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PROCEEDINGS

PAPERS IN THIS NUMBER.

"The Manufacture and Distribution of Gas." By Herbert N. Cheney.

"Gas Holder Design and Construction." By E. F. Miller.

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Contributors are hereby notified that proof will not be submitted to them for examination unless requested before the 10th of the month preceding the month of publication.

BINDING SOCIETY JOURNAL.

THE Secretary has made arrangements for binding Volume 9 of the JOURNAL of the Society. The ten numbers will be bound in one volume, the style of binding to be uniform with that of previous volumes. The price of binding this year will be 75 cents per volume.

Numbers for binding must be sent to 715 Tremont Temple, Boston, before April 1, 1923. After this date, numbers will not be accepted for binding except with the understanding that they cannot be bound at the price named.

MINUTES OF MEETING.

BOSTON, January 24, 1923 — A regular meeting of the Boston Society of Civil Engineers was held this evening in Chipman Hall, Tremont Temple, and was called to order at 7:45 P.M. by the President, Prof. Dugald C. Jackson.

This meeting was a Joint Meeting of the Boston Society of Civil Engineers and the Massachusetts Institute of Technology Student Chapter of the American Society of Civil Engineers. There were about 250 members and guests present.

The minutes of the previous meeting were approved as printed in the January JOURNAL.

The Secretary reported for the Board of Government the names of those elected to membership:

Members — Rufus Edward Bates, John Vincent Corbett, Hall Nichols.

Juniors — Sydney Smith, James Avery Stalbird, Adam Edward Sulesky.

The Secretary announced the death of Carl B. Reed, a member of the Society, who died on December 29, 1922. The President announced that a committee would be appointed to prepare a memoir of Mr. Reed.

The Secretary presented the following amendment to the By-Laws which the Board of Government had voted to recommend to the Society.

To amend Section 8 of the By-Laws by adding:

“A member of any grade who has paid dues for 40 years, or who has reached the age of 70 years and has paid dues for 30 years, shall be exempt from further dues.”

This amendment to the By-Laws was approved by unanimous vote of the meeting. Final action will be taken at the meeting of the Society on February 21, 1923.

The Secretary presented the following resolution concerning the establishment of a National Hydraulic Laboratory which the Board of Government had approved and voted to submit to the Society.

Whereas, a resolution is now before Congress to establish a National Hydraulic Laboratory (S. J. Res. 209) and

Whereas, in the past no provision has been made for the scientific study of the principles which govern the flow and regulation of rivers on a scale commensurate with the importance of the problems involved and the relation of these problems to the safety and economic welfare of the public, and

Whereas, many of the fundamental laws are as yet but vaguely understood and practice is too frequently based on rules deduced from limited experimentation, and

Whereas, in our opinion, the hydraulics of the flow and regulation of rivers can be most safely developed by a continued investigation in a permanent laboratory constructed, equipped and manned on an adequate scale, and

Whereas, the problems involved are of great public interest, and the necessary scale makes impossible the undertaking of such investigations by any educational institution, and the objects are not of a character to appeal to industrial support, now therefore,

Be it Resolved by the Boston Society of Civil Engineers that the resolution now before Congress (S. J. Res. 209) should be made law, and

Be it Further Resolved that copies of this resolution be transmitted to Representatives and Senators from Massachusetts.

This resolution was approved by unanimous vote of the meeting and it was thereupon voted to submit it by letter ballot to the members of the Society for their action.

Prof. D. C. Jackson then introduced Arthur T. Safford, Engineer, Locks and Canals, Lowell, Mass., who presented a paper on "The New Hydro-Electric Development of the Amoskeag Manufacturing Co., at Manchester, N. H." This paper describing the hydraulic and structural features of the development was illustrated with a very complete set of lantern slides.

After a description of the electrical equipment of the plant by H. H. Bodge of the General Electric Company, several of the members took part in the discussion of the papers.

The Society voted its thanks to the speakers for their presentation of these papers, after which the meeting adjourned at 9:30 P.M.

J. B. BABCOCK, *Secretary*,

APPLICATIONS FOR MEMBERSHIP.

[February 15, 1923.]

THE By-Laws provide that the Board of Government shall consider applications for membership with reference to the eligibility of each candidate for admission and shall determine the proper grade of membership to which he is entitled.

The Board must depend largely upon the members of the Society for the information which will enable it to arrive at a just conclusion. Every member is therefore urged to communicate promptly any facts in relation to the personal character or professional reputation and experience of the candidates which will assist the Board in its consideration. Communications relating to applicants are considered by the Board as strictly confidential.

The fact that applicants give the names of certain members as reference does not necessarily mean that such members endorse the candidate.

The Board of Government will not consider applications until the expiration of twenty (20) days from the date given.

ARCHIBALD, WHITTEMORE C., Waltham, Mass. (Age 32, b. Waltham, Mass.) Graduate of Waltham High School and then took a course in structural engineering at Franklin Union evening school. 1910-18 with J. R. Worcester & Co., as structural engineer; 1918-22 with the Waltham Watch Co., as assistant plant engineer; and at present with S. C. Sperry & Co. contractors, of Cambridge. Refers to W. W. Bigelow, C. C. Enebuske, E. A. Norwood, C. R. Perry and J. R. Worcester.

HARRINGTON, DANIEL M., Somerville, Mass. (Age 34, b. Hallowell, Maine.) Spent three years in the University of Maine. He was one year with the City of Augusta, Me.; one year with the Maine Central R. R.; five years with the Boston & Maine R.R.; three years with Massachusetts Highway Department and is at present transitman in the Highway Department. Refers to A. B. Appleton, S. P. Coffin, H. F. Heald and S. Krigger.

HILL, HENRY FRANCIS, Jr., Boston, Mass. (Age 23, b. North Whitefield, Maine.) Graduate of University of Maine, 1922, majoring in hydraulics and received B. S. degree. During the summer of 1921 was employed on instrument and construction work on a Portland cement concrete highway; from the day after graduation until January 6, 1923, employed by Maine State Highway Commission, first in charge of a bituminous macadam highway, next on a preliminary survey in various parts of Maine and last in the drafting

room of the highway department. On January 8, 1923, received a Civil Service appointment as Junior Engineer in the Water Resources of the U. S. Geological Survey in the Boston Office. Refers to H. S. Boardman, G. C. Danforth, C. H. Pierce, M. B. Stackpole and W. D. Trask.

KEEFE, WILLIAM J., Boston, Mass. (Age 36, b. Boston, Mass.) Three years at Mass. Inst. of Tech. 1909-14: with the B. & M. R. R. in the signal engineer's department as draftsman and then inspector; 1914-20 with the Public Service Commission of Massachusetts as assistant engineer of signals; 1920 to date with the Department of Public Utilities as assistant engineer. Refers to J. B. Babcock, C. B. Breed, H. W. Hayes and F. B. Walker.

MCCORMACK, CHARLES DONALD, W. Medford, Mass. (Age 38, b. Somerville, N. B.) Graduate of University of New Brunswick in engineering. 1907-10 transitman with Canadian Pacific Railway; spent the next two years at Mass. Inst. of Tech.; 1913-14 on wharf, bridge and dam construction; 1916-19 draftsman with B. & M. R. R.; 1919-20, oil combustion engineering; 1920 to date engineer with the New England Fuel and Transportation Co., Everett. Refers to C. B. Breed, R. E. Curtis, P. Jones, J. B. Mailey, D. Porter and J. C. S. Taber.

NAIMON, BENJAMIN, Holliston, Mass. (Age 26, b. Millis, Mass.) Graduate of Northeastern College in 1917, in civil engineering. Was rodman with the Boston & Albany immediately after graduating; in July 1918 entered the U. S. Navy as chief machinist's mate for civil engineering duties; at close of war resumed position with Boston & Albany R.R.; from spring of 1919 to early fall was with the Highway Commission in the office and on road construction; October 1, 1919 entered the employ of the Commission on Waterways and Public Lands, State of Mass., and was there until this department became Dept. of Public Works; from November 1919, to the present, he has been instrumentman on topographical and hydrographical surveys of rivers and harbors in the Dept. of Public Works, Division of Waterways and Public Lands. Refers to C. S. Bryer, C. S. Ell, J. N. Ferguson, W. C. Hawley and H. B. Wood.

OTTERTSON, JONAS BERNARD, Framingham, Mass. (Age 29, b. Roxbury, Mass.) Graduate of Northeastern University in 1917. He is at present at an evening course at Northeastern University, Commerce and Finance School. He has had three years' experience in engineering work such as drafting, checking and computing, structural work in concrete, land and railroad track plans. Was a year and a half with American Red Cross in France. At present is inspector of construction with the Boston & Albany R. R. Refers to C. S. Ell, A. Curtis, F. L. Flood and F. V. Wright.

PHILLIPS, LAURENCE J., Watertown, Mass. (Age 27, b. Cambridge, Mass.) Graduate of Northeastern University. From August 1914, to January 1, 1915, with Whidden & Co., engineers and builders, as time keeper, stock clerk and draftsman on structural steel details; from January 1, 1925 to date, with Whidden-Beekman Co., (formerly Whidden & Co.) on design and detail of foundations and structural steel, estimating and resident engineer

in responsible charge of construction work; at present engineer in charge of construction work and estimator. Refers to W. A. Brown, A. S. Coombs, W. S. Fox, L. L. Street and J. A. Tomasello.

RANKIN, ELMER P., South Braintree, Mass. (Age 26, b. New Bedford, Mass.) Educated in the public schools of Boston then took a course in structural engineering at Lowell Institute, Mass. Inst. Tech. From May, 1914, to November, 1915, was draftsman and inspector for William S. Johnson, Boston; April, 1916, to September, 1917, architectural draftsman; September, 1917, to April, 1918, structural draftsman with Stone & Webster, Inc.; April, 1918, to August, 1918 and March, 1919, to July, 1919, structural designer with Fay, Spofford & Thorndike; August, 1918, to March, 1919, in U. S. Army; July, 1919, to January, 1920, structural designer with Harry M. Hope Engineering Co.; January, 1920, to April, 1921, structural designer and estimator with Lockwood, Greene & Co.; August, 1921, to date, engineer in charge of estimating and designing for Hedman Products Co. Refers to W. W. Bigelow, J. S. Lamson, W. F. Pike, H. E. Sawtell, H. C. Thomas and E. A. Varney.

ROPES, LAWRENCE G., Salem, Mass. (Age 25, b. Salem, Mass.) Graduate of Tufts College with degree B.S. in civil engineering, and one year at Mass. Inst. Tech. Experience — summer of 1918 draftsman with Fay, Spofford & Thorndike; summer of 1919 draftsman with Lockwood, Greene & Co.; six months, 1920-21 with Boston Bridge Works; 18 months with Phoenix Bridge Co., drafting, designing and estimating; at present instructor in civil engineering department at Mass. Inst. Tech. Refers to H. K. Barrows, J. S. Lamson, K. C. Reynolds, C. M. Spofford and H. Sutherland.

LIST OF MEMBERS,

ADDITIONS.

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BATES, RUFUS E.	63 Avalon Ave., Quincy, Mass.
GANNON, GEORGE H. P.	Whitin Mch. Co., Whitinsville, Mass.
GLYNN, THOMAS P.	4 May St., Jamaica Plain, Mass.
HUNT, ARTHUR W.	67 Minot St., Dorchester, Mass.
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PROCEEDINGS.

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CHANGE OF ADDRESS.

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LUCAS, JOHN, Chicago Bridge & Iron Works, 30 Church St., New York, N. Y.
SMITH, MERRITT P.....613 Washington St., Waukegan, Ill.
YOUNG, ERVING M.,.....833 E. Delevan Ave., Buffalo, N. Y.

DEATH.

FRANK W. HODGDON.....January 26, 1923.

LIBRARY NOTES.

RECENT ADDITIONS TO THE LIBRARY.

U. S. Government Reports.

Bureau of Yards and Docks, Annual Report of Chief of 1922.
Fourteenth Census of United States. Vol. XI. Mines and
Quarries.

Water Supply Papers, 473, 486 and 507.

State Reports.

Massachusetts. Annual Report Department Public Utili-
ties, Part 2, Section 1. 1921.

Massachusetts. Annual Report Metropolitan District Com-
mission. 1921.

Massachusetts. Annual Report Department of Public
Works. 1920.

New York. Annual Report State Department of Health.
Vol. 1. 1920.

Municipal Reports.

New York. N. Y. Annual Report (Summary) Transit
Commission. 1922.

Miscellaneous.

McGraw Central Station Directory and Data Book. 1921-
1922.

Railway Statistics of United States of America. 1921.
Slason Thompson.

LIBRARY COMMITTEE.

BOSTON SOCIETY OF CIVIL ENGINEERSFOUNDED 1848

PAPERS AND DISCUSSIONS

This Society is not responsible for any statement made or opinion expressed in its publications

THE MANUFACTURE AND DISTRIBUTION OF GAS.

BY HERBERT N. CHENEY.* MEMBER OF THE BOSTON SOCIETY OF CIVIL ENGINEERS.

(Presented December 20, 1922.)

FROM the beginning of the use of gas until about 1880, it was used almost entirely for illumination in open flame burners. Then came the introduction of the electric light, followed closely by the mantle gas light.

The mantle gas light enabled the gas companies to keep for a time a large portion of their lighting load in spite of the tremendous growth of electric lighting.

In the 90's began the real use of gas for cooking and for heat in some industrial appliances. So that we find in 1900, about 80 per cent. of the gas sold was used for lighting and about 20 per cent. for cooking and industrial uses.

Today these proportions are almost exactly reversed; about 20 per cent. of the output being used for lighting and about 80 per cent. for cooking and industrial uses, and the output of gas is more than three times what it was in 1900. The total output of manufactured gas in this country is now about three hundred twenty-six billion cu. ft. per year. Boston uses about 2 per cent. of the quantity or 6 370 000 000 cu. ft.

The industrial field for the use of gas has not been tilled — just scratched a little. The domestic cooking field is only half

* Vice-President, Boston Consolidated Gas Company.

cultivated, and there is another domestic use of gas now assuming importance, namely auxiliary house heating. (I specify "Auxiliary" house heating because complete house heating cannot be a proper and economical use of gas until there are further developments in production and in rate making.)

While there are many people who realize that the best quality of light obtainable by artificial means, is that obtained from mantle gas lamps, it is nevertheless probable that the use of gas for lighting will not grow much and it will probably slowly decrease, as it has during the time since 1900.

You will notice that the actual loss in the use of gas for lighting during this time is about 25 per cent. of the use for that purpose in 1900; a slow decrease, and one that is almost negligible when considered with the growth in other uses.

At any rate the use of gas in the other fields should increase so much that gas for lighting will soon be a relatively small and unimportant percentage of the total output.

So much just to show you that we are not talking ancient history but that our subject is connected with an important, living, growing public service, Mr. Babson to the contrary notwithstanding.

HINDRANCES TO GAS DEVELOPMENT.

Suppose someone connected with the gas industry has ideas. To try out these ideas is more or less costly. If the apparatus to try them out is built and does not prove successful, who stands the loss?

If it does prove successful, what happens? The selling price of gas is ultimately if not almost immediately reduced so that the dividends shall be no greater than they were before.

Under these circumstances, do we have ideas, or having them, do we attempt to put them into execution? Yes, we do, but with the possibility of loss, and the certainty of no very great return, it is very difficult to get money to spend on experiments.

Again — Under State laws a Gas Company is obliged to furnish gas of a certain minimum heating value. We have seen an enormous change in the character of the use of gas in the last

twenty years. The question of what is the proper standard for gas in any given locality is a difficult one to determine.

First, the question of raw materials available is the most important factor.

Second, the question of what the greater portion of the gas is used for is also important.

Gas engineers are not entirely agreed on the solution of this problem but on one point they are unanimous — that it can only be determined by actual, commercial, practical, experiments, and when we undertake to do this we are confronted generally by a law passed to fit conditions several years ago, and it is very difficult to get any change or any latitude of action for experimental purposes.

Some engineers even go so far as to advocate the entire abolition of standards, inasmuch as it is only by experimenting and determining the most desirable quality of gas to be made in any given locality, that we can put ourselves in a position to compete with other fuels, and these men feel that competition is a better regulator than a statute.

The first manufactured gas was made by distilling coal, and much is still made and will continue to be made in this manner. In this country today about 40 per cent. of the total gas made is coal gas.

In the 1880's the manufacture of carburetted water gas was begun. A water gas plant compares with a coal gas plant as follows:

- Lower investment cost per unit of capacity.
- Less ground space required.
- Less operating labor cost but higher material cost.
- Much greater flexibility.

It is this last quality which is of the greatest importance. Coal gas works with their large masses of hot brick cannot be run properly to care for outputs of gas varying greatly from day to day.

The coal gas works also is obliged to dispose of its principal by-product, coke, and this may be almost impossible for quite long periods.

The water gas plant has no by-product worth mentioning and uses coke as its fuel.

In passing, it is perhaps well to mention the subject of by-products. A very exaggerated idea of the value of the gas house by-products is commonly held. There are none in either process that are worth mentioning except coke, tar and ammonia.

Coke is by far the most important, but except in times of fuel shortage may be very difficult to sell, particularly in a section of the country like New England which is addicted to the use of anthracite.

Tar and ammonia are not very valuable, as not enough of either is produced to effect the price of gas greatly. We all know of the enormously valuable things that are made from tar but we are apt to forget that the reason for their value is either that they are present in minute quantities or that the processes of extraction are tremendously expensive.

Still we often hear it said that if we would only save our by-products, we could make gas for next to nothing. This is not so.

To resume — The water gas plant provides the gas works with the desirable flexibility of operation, and furnishes an outlet for the coke from the coal gas works.

The ideal works, therefore, contains both kinds of plant; the coal gas plant making just enough coke to care for the needs of the water gas plant, and the water gas plant taking care of the variations in the output.

This would result in a make of from 15 to 30 per cent. coal gas, depending on the type of coal gas plant, the balance being water gas.

The plant (Fig. 1) which we show you tonight is illustrative of present practice in water-gas making. It does not contain all the modern refinements and aids to operation, but it is as nearly as may be an exact model on a scale of one inch per foot of a modern water gas plant capable of making about two million cu. ft. in 24 hours.



FIG. 1. — MODEL OF WATER GAS PLANT.

Working model to the scale of 1 in. per ft. of modern water gas plant capable of making about 2 000 000 cu. ft. in 24 hours.

PROCESS OF MANUFACTURING WATER GAS.

Water gas is made by passing steam through incandescent coal (or coke), the steam, or water, H_2O , uniting with the carbon of the fuel, C, to form hydrogen, H_2 , and carbon monoxide, CO. $H_2O + C = H_2 + CO$.

This gas, which is commonly called, blue gas, is non-luminous and has a heating value of about 300 B. T. U. per cu. ft.

It is therefore enriched by the addition of oil gas or vapor so that the resulting gas has a heating value above the State requirements of 528 B. T. U. per cu. ft.

The first thing required in making water gas is a bed of incandescent fuel in the "generator," a gas-tight steel shell lined with refractory material. This fuel may be anthracite or coke, and just lately some machines, slightly modified are using bituminous coal. Coke is most commonly used.

Air blowers are necessary to raise the temperature of the fuel to the desired point.

During the "blow" the products of combustion pass through other shells (carburetter and superheater) and escape at the stack.

Additional or secondary air is admitted at the top of the carburetter sufficient to complete the combustion of the blast gases from the generator. The heat from this secondary combustion is stored in the firebrick, or checker brick with which the carburetter and superheater are filled. We will refer to this stored heat a little later.

The temperature in all three shells having been brought to the desired points, the "blow" is ended and the run is begun. The blast is shut off and steam is turned into the ash pit. Passing up through the fire this steam with the carbon forms the blue water gas (300 B.T.U.).

Oil is now sprayed into the top of the carburetter. The stored heat in the checker brick vaporizes and cracks this oil, resulting in the formation of fixed gases, and oil vapors which mix with the blue gas and enrich it to the desired heating value. Some of the oil vapors, however, are such only at the temperatures obtaining in the set, and are deposited later on in the process.

The injection of steam and oil is continued until the temperatures in the set have fallen somewhat when the oil is shut off, and a little later the steam is shut off. The blast valves are opened again and the heats are recovered. This whole cycle may take five minutes, say two minutes blow and three minutes run.

At the beginning of the run, when steam is turned on, the stack valve is closed so that the gas made cannot escape. The gas therefore passes through the "wash box" which is nothing but a kind of check valve with water acting as the gate.

You will see that with an inlet pipe just dipping below the water level the gas under pressure can easily force itself through the water in one direction but cannot flow backward when this pressure is relieved by opening the stack valve because the water will rise in the dip pipe.

In the wash box, which is kept constantly supplied with water, the gas is cooled considerably and much of the heavier oil vapor (known as water gas tar) is deposited.

Next we have the condenser or cooler where the temperature is further reduced, and more tar and excess water vapor are deposited; and so to the relief holder.

So far the gas still contains a quantity of tar in the form of mist, and all its sulphur impurities. To force the gas through apparatus for the elimination of these requires some pressure and the best results are obtained by constant flow. Therefore, the relief holder is used to relieve the gas making sets of excessive pressure and to allow the gas to be pumped through the remaining pieces of apparatus at a uniform rate, as you will remember that the gas is produced intermittently.

From the relief holder, the product passes through the exhausters (or rotary pumps) through the shavings scrubber (which is just what its name implies, shavings on trays, where the last traces of tar are deposited) through the purifiers, the station meter, to the storage holder.

The purifiers are simply large boxes filled with iron rust on shavings. In its passage through this purifying material (commonly called oxide, although it isn't an oxide) the sulphur in the gas, mostly in the form of sulphuretted hydrogen is removed

forming a compound of iron and sulphur, which on being removed from the purifiers and exposed to the air will revivify or give up its sulphur, take oxygen from the air and become usable oxide again. This won't go on forever, unfortunately, as the oxide finally becomes coated with dirt and free sulphur to such an extent that it is no longer usable.

This in a sketchy way is an outline of the water gas making process.

DISCUSSION.

MR. CHENEY in response to questions resumed:

It takes about twenty men on a shift to operate one plant containing only one set, about twenty-five men on a shift to operate a plant containing two sets.

With reference to the length of the run, I said it ran until the temperature had fallen a certain amount. That applies to this plant and to most larger plants. The temperature of the fire, so far as I know, is almost never known. The temperatures of the carburetter and the super-heater are, in larger plants, measured by pyrometers. If the temperature of the fire is low there will be produced instead of the simple reaction which I mentioned a certain percentage of carbon dioxide as well as monoxide. That carbon dioxide is, of course, an inert gas which doesn't burn and isn't valuable. Trial must be made and after the cycle has been obtained the run is continued on a certain time. Of course there are other variations. The air pressure and the steam pressure, are varied.

If full pressure of steam is used in the generator it might amount to 35 or 40 in. of water, or $1\frac{1}{2}$ lb. Something like that. The use of exhaust steam, which has recently been utilized has resulted in some economy. It can be used at the expense of a little back pressure on the apparatus, say 5 or 7 lb. Exhaust steam can be used which meets all the requirements for making water gas.

It is not always an advantage to use superheated steam which has been mentioned. One practicable consideration is the character of clinker formed in the generators. It must be possible to clean the fire. It is fairly common practice to run any where

from five to eight hours without cleaning the fires. Clinkers must be formed sufficient to hold up the fire above them and yet soft enough so that they can be fairly readily broken up with slice bars. Under certain conditions which might be made worse by too highly superheated steam, it takes three or four hours to do this, whereas ordinarily it takes twenty-five minutes.

BOSTON SOCIETY OF CIVIL ENGINEERS
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PAPERS AND DISCUSSIONS

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GAS HOLDER DESIGN AND CONSTRUCTION.

By E. F. MILLER.*

(Presented December 20, 1922.)

As neither the consumption, nor the manufacture of gas is at a uniform rate during the twenty-four hours, provision for storage is a necessity.

The amount of this storage capacity, relative to the daily consumption is determined by each company, from its experience with the demands of its particular territory, and by the capacity and design of the generating plant. At one time, it was thought necessary to provide storage of from 75 per cent. to 150 per cent. of the maximum output, but if this ratio obtained today, the gas holder building capacity of the country could not meet the demand. From 30 per cent. to 90 per cent. is now sufficient, the lower figure usually being a case of necessity, *i e.*, lack of capital.

Having decided to build a holder of a certain capacity, the limits of diameter are fixed by the boundaries of the land available. The diameter will influence the pressure thrown by the holder, although usually the maximum pressure is in excess of that needed. The minimum pressure, that of the inner lift, will, however, be determined by the needs of the distributing system.

These matters settled, the company will then decide on the kind of water tank, whether of masonry, built in an excavation,

* Consulting Engineer.

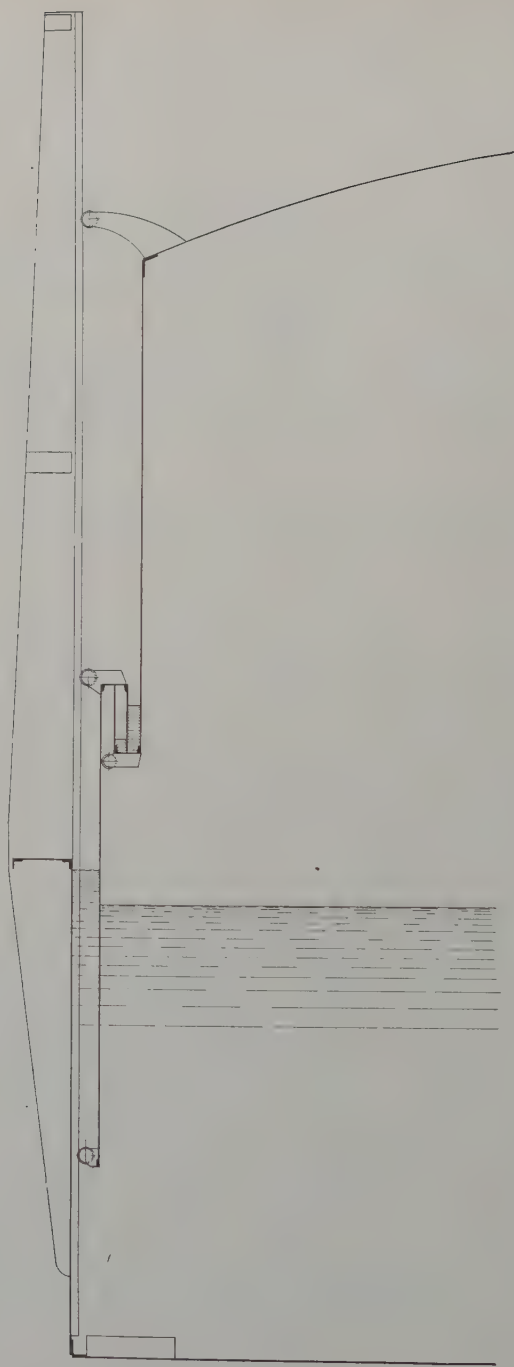


FIG. 1. — GENERAL ARRANGEMENT SHOWING CUP
AND WATER SEAL.

or of steel construction, built on a concrete foundation approximately at the general level of the site selected.

A gas holder is a very simple affair, merely an inverted bucket or bell, floating on gas, collected above the surface of the water, inclosed in a tank. The chemists collect gas in the laboratory in a glass bell, the gas usually under suction, entering through a bent glass tube, as the level of the water recedes — until the receiver is filled. In the laboratory the bell does not float.

When it became necessary to provide storage for illuminating gas, in the early installations, this laboratory device was adopted and adapted, the bell being made of iron sheets, floated on water in a tank of brick masonry or in a wooden, or a cast-iron tank. The pipes were carried under the bottom, and turned upward inside to reach above the surface of the water. The bell floating on the gas, sealed by the water, was guided by posts, standing on the tank wall.

These single lift holders were soon developed into multiple lift designs, called telescopic, by the device of the cup, carrying water to make a seal between the lifts. (Fig. 1.)

The early wooden guides were replaced by columns of cast iron, later of rolled metal construction, design being architectural, developing into round columns, with ornamented capitals, but without much thought being given to providing resistance proportional to the load. (Figs. 2 and 3.)

As demand for large capacity holders arose, it became necessary to study design more carefully, resulting in frames built of rolled structural shapes. Sir George Livezey of the South Metropolitan Gas Company in London was the leader in this type of construction.

Beside the conventional vertical guiding, other methods have had a limited use. The wire rope arrangement, omitting the frame entirely, is not a bad system for single lifts, but only an enthusiast will use it for multiple lifts. Quite a number are in use in England.

A system of spiral guiding is installed rather successfully in England, where a four lift holder of 5 000 000 cu. ft. capacity was built, but the spiral system has not come into use in this country. (Fig. 4.)

Holders consisting of circular disks or crowns with packing at the circumference, moving vertically in steel cylinders with smooth inside surfaces have been built in Belgium and Germany. These are of small capacity.

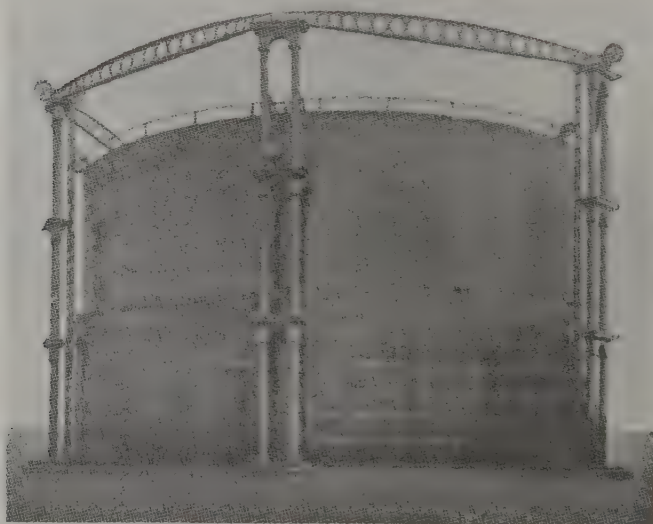


FIG. 2. — TWO-LIFT HOLDER WITH CAST IRON FRAME.



FIG. 3. — SINGLE LIFT HOLDER WITH CAST IRON FRAME IN MASONRY TANK, 200 FT. DIAMETER.
Gerard Street, Boston.

TANK.

Where conditions demand the selection of the masonry tank, it is now built of reinforced concrete.



FIG. 4. — SPIRAL GUIDING — GADD'S DESIGN.

The masonry or concrete tank is rather more expensive than the steel tank, in first cost, but it has the advantages—of no depreciation, no maintenance cost, freedom from ice, and freedom from damage to surroundings in case of rupture. So far as our knowledge goes, but one large steel tank has failed.

Where ground water level permits, the tank is designed to have the top curb, at, or slightly above surface grade. A circular excavation, similar to a sewer trench is made and lined with water tight sheathing — and the circular wall of masonry or concrete built inside. The interior earth is then removed as desired, leaving a mound, which is covered with concrete and the bottom made water tight. For some years, concrete has been used exclusively, for the wall.

The sheet piling is withdrawn, and earth filled in on the outside and puddled.

In the earlier constructions of stone or brick masonry, dependence was placed on the earth resistance on the outside of the wall to prevent rupture from the weight of the water inside but in the later designs for concrete construction sufficient reinforcing bars are inserted to resist the unbalanced water pressure, after figuring the earth resistance. Naturally each case is special and the wall must be designed to suit the conditions. Where the top of the tank is above original surface grade the earth taken from the inside is filled around the wall, and graded into a suitable slope.

Concrete Tanks.

Concrete tanks, usually, are in one of the two classes, one in which the concrete takes the tension, caused by the water pressure, and the other in which the steel reinforcement is sufficient to resist the stresses.

In both cases, the forces acting upon the tank wall are the same. The water pressure on the inside varies in intensity with the depth. Since these tanks are usually wholly or almost entirely underground the active pressure of the earth on the outside of the wall must be considered as well as any outside water pressure. The passive resistance of the earth is an added factor of safety, since this resists the radial deformation of the tank. In designing a retaining wall we use the maximum possible earth pressures, but in a tank we only use the pressure we are certain to get, and if the actual pressure is greater than that assumed, it adds to the safety of the tank.

If the holder tank is in dry homogeneous earth, the outside pressure will also vary in intensity with the depth, depending upon the weight of the earth and its angle of repose. If the earth is saturated, owing to the outside water level being above the bottom of the tank, the outside pressure will vary directly down to the line of saturation; below this point the pressure should be figured for submerged earth at the angle of repose and weight of submerged earth and carrying a surcharge of dry earth above the line of saturation. Then the full pressure due to the head of water below the line of saturation should be added to the outside forces. The algebraic sum of the inside and outside forces gives the loading for which the wall is to be designed. The well known formula for ring tension, $T = pr$, where T is pounds tension in a section of the wall a foot high, p is pressure in lb. per sq. ft. at any given point and r is the inside radius of the tank in feet, is used.

In the case of the plain concrete tank the thickness of the wall is made such that the tension T divided by the area of the wall at the given point shall not exceed 90 to 100 lb. per sq. in. for 1 : 2 : 4 concrete.

If $\frac{1}{2}$ of 1 per cent. steel is used, the steel can be considered as 15 sq. in. of concrete for each sq. in. of steel in the cross section, assuming the ratio of the modulus of elasticity of steel to that of concrete as 15 to 1. In the case of the tank with sufficient steel to take all of the tension T , the stress should not exceed 16 000 lb. per sq. in., and the thickness of the wall is made such that is the whole of T is taken by the concrete the strain would be about 250 lb. per sq. in. for 1 : 2 : 4 concrete. It has been found more economical to make the outside of the top of the wall cylindrical, rather than to build pilasters for the base plates of the standards. This necessitates a thicker wall at the top than is required to resist the ring tension, but the mass is useful in resisting the uplifting and racking stresses set up by the wind on the holder and guide frame.

In some tanks the restraining influence of the bottom, which cuts down the ring tension through a portion of the height of the wall, is figured and a reduction in wall thickness thereby gained, but it is better practice to make the wall with a joint at the

bottom which can be filled with asphalt, as this greatly simplifies the construction of the bottom, and avoids the likelihood of cracks.

The tank bottoms are usually made 12 in. or so in thickness and reinforced for temperature stresses. The bottom is simply to make the tank water tight and in most cases cannot be made to resist much of a head of water outside.

In case the outside head is greater than can be resisted by the weight of the concrete slab, the usual practice is to place vent pipes in the bottom slab, which are left open until the tank has been filled with water for a few feet, when the pipes are closed. These vent pipes relieve the bottom slab of outside pressure in case of failure of the pumps before the holder is filled with water.

Dimensions.

As a matter of interest the dimensions of some large masonry tanks are given:

Astoria Holders — 15 000 000 cu. ft. capacity, 5 lifts, pressure 15.5 in. water. Reinforced concrete tank, 300 ft. $\times$ 48 ft. 3 in. Frame — 30 standards — 235 ft. 8 in. high.

Manchester, England — 10 400 000 cu. ft., 4 lifts in masonry tank, 285 ft. diam. $\times$ 43 ft. deep.

Melbourne Holder — 12 500 000 cu. ft., tank 300 ft. $\times$ 48 ft., 34 standards, 4 lifts, Piggott cups, 2 48 in. I. and O. Partly in solid rock.

Boston, at Commercial Point — 10 000 000 cu. ft., 273 ft. 6 in. $\times$ 39 ft. reinforced concrete.

Boston, at Everett — 6 000 000, 235 ft. $\times$ 39 ft. concrete in earth, reinforcement for temperature stresses.

Boston, at Hilton Street — 190 ft. 3 in. $\times$ 40 ft. 10 in., concrete with flat bars inserted in series as bands.

East Boston — 2 000 000 cu. ft., 151 ft. $\times$ 31 ft. 9 in., concrete.

Boston, Gerard Street — 201 ft. 4 in. $\times$ 40 ft. 3 in., masonry.

Oldham, England — 5 400 000 cu. ft., spiral guided, masonry tank 212 ft. $\times$ 41 ft., walls 7 ft. thick at the bottom, tapering to 2 ft. 9 in. at the top.

Steel Tanks.

As the capacity of rolling mills to turn out large plates developed, the use of tanks made of steel plates increased rapidly, especially in this country. The first tank of riveted plates of large size was built in New York, about 1886, but it was a little ahead of mill capacity as the shell was built of two thicknesses of plates, the seams breaking joints. This tank is still in use and was in good condition, at least up to a year ago. The use of steel was at first, a little uncertain, as Bessemer plates were hard and inclined to be brittle, but the open hearth process made such progress that by 1894, a tank 195 ft. diameter $\times$ 49 ft. deep for a 5 000 000 cu. ft. holder was built for the East River Gas Co., at Long Island City. (Fig. 5.)

Steel tanks are built upon a concrete pad, from 10 in. to 18 in. thick which may rest directly upon the supporting earth where investigation has proved its bearing power sufficient, but where earth resistance is uncertain, the area is piled and capped. Where wooden piles are used, excavation is made and the piles sawed off, at or below water level, the concrete pad may then be put in or a filling of sand and gravel carried up to near grade, and the pad placed at approximately surface level. Where the foundation is sunk in the earth a circular wall usually is built about 4 ft. outside from the tank. Occasionally the tank shell is well painted, and the filling brought up close, grout or tar being poured next to the steel plates.

In designing the foundation, the weight of the water in the tank furnishes practically all of the load. If 40 ft. deep, the pressure is 2 500 lb. per sq. ft. to which is added the weight of the tank bottom — say 12 lb. — and the weight of the concrete — say 200 lb. Around the circumference there is a dead load due to weight of tank shell and frame, and wind resistances.

As the pad is made thicker at the circumference and the area of pressure increases at an angle of 45 degrees from the tank bottom curb — the added load is distributed. At the most it will not add over 500 lb. per sq. ft. on an annulus about 6 ft. wide.

The tank bottom is from $\frac{3}{16}$ in. to $\frac{3}{8}$ in. thick, the plates joined by single riveting. As the riveting is done with the plates

supported, about 30 in. above the concrete, reinforced holes are provided for insertion of the lowering screws. After landing, grouting may be run under the plates, through these holes.

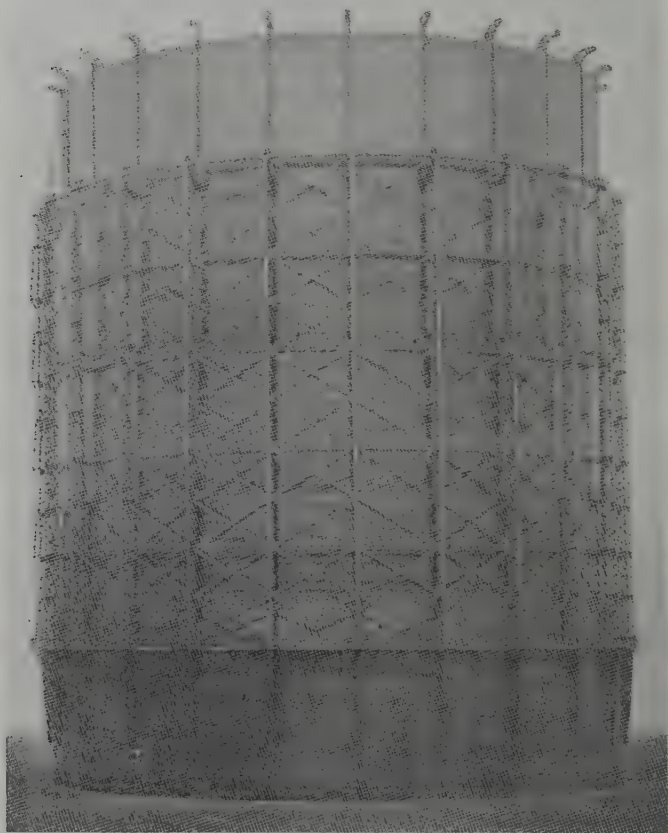


FIG. 5. — 5 000 000 CU. FT. GAS HOLDER IN STEEL TANK.
Erected 1894.

They are then closed. The reinforcement may be a pressed steel flange, in which a pressed cap may be welded or riveted.

The bottom and shell of the tank are joined by an angle curb, which may be placed either inside or outside the shells.

For convenience of riveting and calking, an inside curb is to be preferred. The outside curb has the theoretical advantage that the rivets in the vertical leg are not in tension, but this is not important here as the structural loads carried by these rivets is confined to shear. Tension on these rivets is not a structural load, and if excessive, can only cause leakage, and is low — as may be figured —

Assume tank 50 ft. deep. $50 \times .43 = 21.50$ lb. per sq. in. — hydrostatic pressure.

Assume first course — 46 in. wide, and that influence of lower rivets extends half way up — $21.5 \times 23 = 435$ lb. per in. of circumference. Rivets $1\frac{1}{2}$ in. diam. $\times 4\frac{1}{2}$ in. pitch.

$$\frac{435 \times 4\frac{1}{2}}{\text{area } 1\frac{1}{2}} = \frac{1960}{1.77} = 1\ 100 \text{ lb. per sq. in. tension in rivets.}$$

The plates of the tank shell may be strained to 16 000 lb. per sq. in. of net section. The material should be of quality suitable for bridges (Class A) taking base price. Occasionally boiler steel is demanded, but a higher grade is an unnecessary expense. The strain is uniform, there is no similarity to a boiler, the temperature being practically even.

The vertical seams in plates over $\frac{7}{16}$ in. thick, are usually butt strapped, with a joint efficiency of 86 to 94 per cent. This is obtained by using a wider butt strap on the inside. Horizontal seams are lapped and single riveted. The top of the tank shell is finished with a curb or walk plate which may be from 24 in. to 60 in. wide. This curb has the function of a circular girder to resist distortion from the horizontal shear due to wind at the base of the frame.

Beneath the walk plate are the vertical supports or tank standards, secured to the shell of the tank by riveted connections. These members carry the weight of the frame, and the vertical loads to the tank shell plates and distribute the horizontal shear at the curb. Just how much they assist the top curb to maintain its rigidity, can only be investigated by complicated calculations, involving application of theories of elasticity. The top curb — unassisted — is not a very efficient base for the frame. The walk plate is further stiffened on the web, and

connected to the top course of the shell by triangular brackets, spaced between the standards.

Inside the tank shell are the vertical guides, or rails, for the rollers on the lower curb of the outer lift of the holder. Landing blocks are distributed around the circumference of the bottom, on which the holder shells rest when not inflated.

The inlet and outlet pipes, are led from the outside, under the foundations, to a foot bend, resting on a special foundation and the vertical leg carried upward through the tank bottom to a level, slightly above the top curb, so that no water can overflow into them. Where passing through the tank bottom, a special flange is used, riveted or bolted, and calked. With large holders it is the custom to build tunnels beneath the bottom, for the pipes. These tunnels are left open so that no vertical load may come on the pipes, which are usually of cast iron, but of late years, when larger than 30 in. diameter of riveted construction.

Originally, holders had but one pipe, then two, but now three or four are placed, and have economical use. When the diameter is over 48 in., the cost of fittings and valves, is relatively excessive.

The weight of the tank bears a rather definite ratio to the volume. Including the stairway, guides, curb, landing blocks, it will run from 1.35 lb. to 1.70 lb. per cu. ft. of volume.

Where the tank bottom is $\frac{1}{4}$ in. thick, the shell strain 16 000 lb. and the ratio of depth to diameter, say 1 to 5, the ratio is about 1.50. Several examples are given as follows:

Diam. 189 ft. 9 in. — depth 48 ft. 10 in. — $\frac{5}{16}$ in. bottom — 15 000 lb. strain; ratio 1.70 lb. per cu. ft.

Diam. 189 ft. 9 in. — depth 40 ft. 7 in. — $\frac{3}{8}$ in. bottom — 15 500 lb. strain; ratio 1.69 lb. per cu. ft.

Diam. 192 ft. — depth 36 ft. — $\frac{5}{16}$ in. bottom — 15 000 lb. strain; ratio 1.47 lb. per cu. ft.

Diam. 195 ft. — depth 38 ft. 4 in. — $\frac{5}{16}$ in. bottom — 16 000 lb. strain; ratio 1.54 lb. per cu. ft.

Diam. 110 ft. $\times$ 31 ft. — $\frac{1}{4}$ in. bottom — 16 000 lb. strain; ratio 1.43 lb. per cu. ft.

Diam. 125 ft. 6 in. $\times$ 31 ft. — $\frac{1}{4}$ in. bottom — 16 000 lb. strain; ratio 1.36 lb. per cu. ft.

Diam. 258 ft. $\times$ 36 ft. 11 in. — $\frac{5}{16}$ in. bottom — 15 000 lb. strain; ratio 1.55 lb. per cu. ft.

Rivets may be in shear according to building laws — 9 500 to 10 000 lb. — butt straps about 90 per cent. plate tension — bearing on rivets 18 000 to 20 000 lb. per sq. in.

The design of rivets 1 in. and over in diameter is a matter of importance. Chamfered corners of rivet holes are desirable



FIG. 6. — TYPICAL JOINT FOR LOWER COURSE OF TANK SHELL.

at the driven end of the rivet, and chamfering of holes both inside and outside, has been used, requiring special rivets with a fillet under the head. Hydraulic machines are almost imperative for rivets $1\frac{1}{4}$ in. diameter and over. Such rivets of large size may be driven cold, but it is preferable to secure a uniform heat, care being taken that the metal is not injured. As the rivet contracts in the hole, it is sometimes desirable to take a second squeeze, with a suitable die, bringing the pressure directly on the axis of the rivet.

In the design of a heavy butt strap joint, care must be taken, that the shortest line of possible fracture be on a vertical line through centers of rivets, rather than on a zig-zag line, passing alternately between holes of adjacent rows. This is taken into account in spacing the outer rows, containing two or

three rivets, somewhat further apart, than the rows nearer to the vertical center line of the joint. (Fig. 6.)

The average pressure on a course, is taken as the lower line of rivets and the width of the course is the distance between centers of horizontal rows of rivets. (Fig. 7.)

In especially narrow courses, the entire width, with rivet holes subtracted, is taken in figuring the section for tension.

The aid of the bottom, to the lower course, may be figured by making assumptions and using formulas for elasticity, which involve considerable guessing, but such design results in a lower course, less in thickness than the second course, which rather offends common sense, and is not readily accepted.

Some years ago, a German concern developed a steel tank design, where the strains are supported, vertically, rather than horizontally, the shell bulging outwards. This evidently was an effort to avoid use of large heavy plates, as German mills were not equipped to roll them. There is economy of material, but higher fabricating cost in the construction. A large part of the material saved in the shell is put back in the top curb and in the vertical compression members. (Fig. 8.)

No certain method of laying out a profile for this shell has been developed, but it is necessary to cut and try, finally arriving at a line, that will keep its shape, when the tank is full; but this line is subject to distortion when filling, for which reason the plates and compression structure must be well united. This design has not obtained a foothold, outside of Germany, Austria and France.

The German builders of the spherical tank claim that the tank weighs .95 lb. per cu. ft. of volume, but whether this is the volume of the rectangular cross section or whether it includes the volume out to the shell is uncertain.

Steel tanks have been built with a steel housing, inside the water space, under which tools, shops and materials were stored; entrance being through the foundation walls, which were built above the ground surface. One at Hamburg collapsed, with loss of life. Investigation brought out that the design was strictly inside the building laws of the city, but the calculations by outside engineers showed a factor of safety of only 1.1.

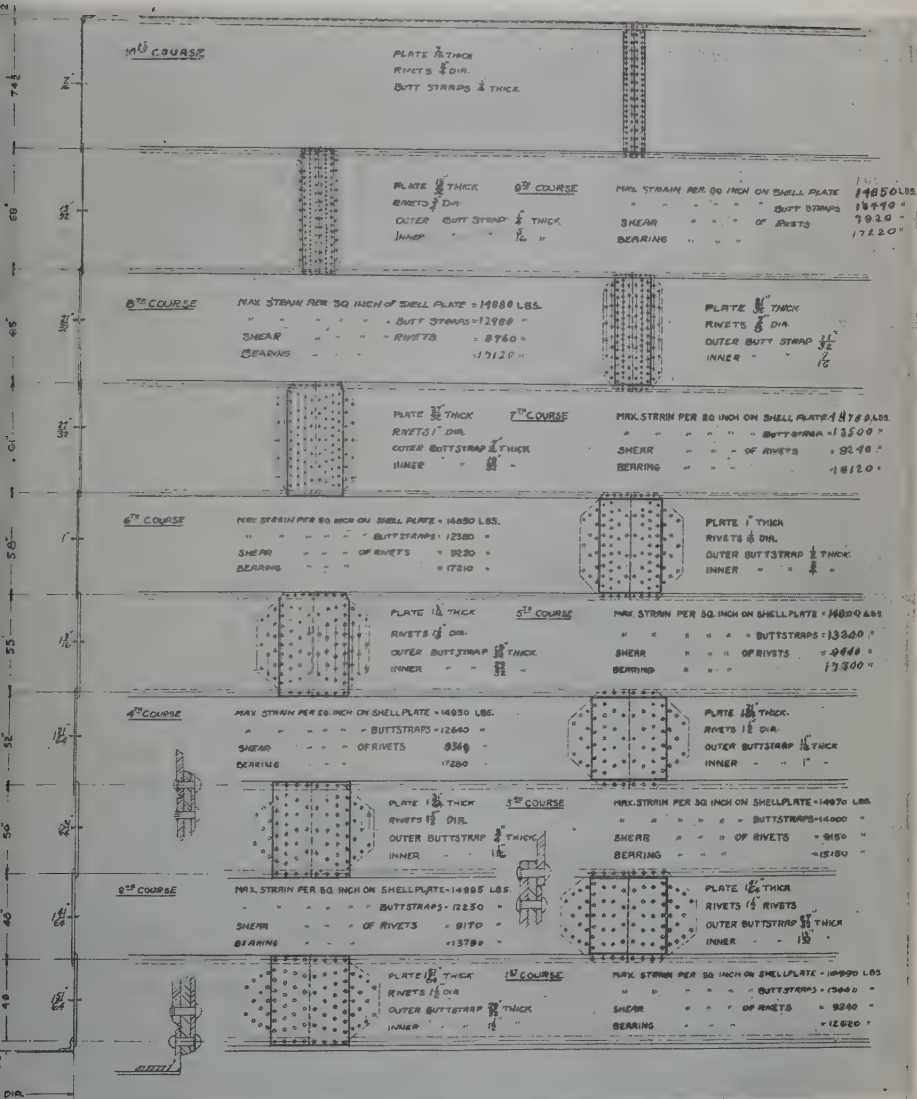


FIG. 7.—STRAIN SHEET OF STEEL TANK FOR 6 000 000 CU. FT. HOLDER.

The Holder.

The gas holder proper (the vessel containing the gas) being an inverted bucket floating on gas, in a water seal, is in unstable equilibrium, requiring lateral support or guiding, as the bell, or vessel rises and falls. The guiding struture must be sufficiently rigid to resist the unbalanced snow load on the crown and the wind pressure, which may be applied in any direction.

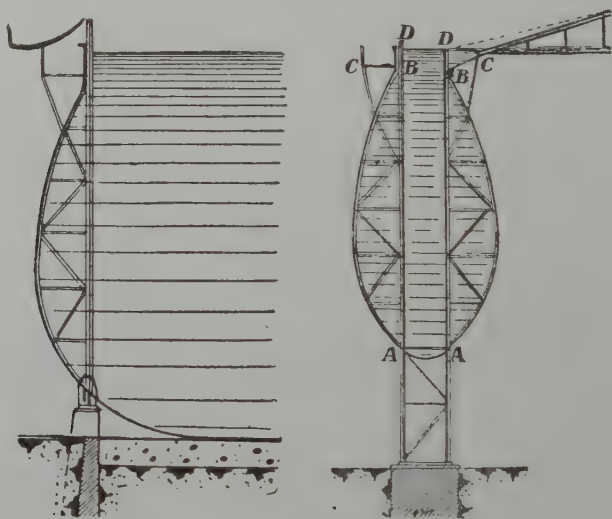


FIG. 8. — PEAR SHAPED STEEL TANK.
Built by M. A. N. Company, Nuremburg, Germany.

The holder structure is a circular shell, with spherical top or crown, all subject to the pressure of the confined gas. The curb, uniting the crown to the shell, is in compression.

All large holders are now built telescopic, with from two to six lifts, each settling inside the next outer, when all are on the landing blocks. (Fig. 9.) The crown is supported by a permanent wooden frame work, built on and anchored to the tank bottom. Each lift is provided with a cup to carry water, making the seal with the next outer lift, as gas is pumped in and the holder inflated. The space between the water and the crown, must be carefully purged of air, as inflation begins. Due to the difference



FIG. 9. — 6 000 000 Cu. Ft. FIVE LIFT HOLDER.

in specific gravity between air and gas, the air escapes through a purge pipe with its inlet near the water surface as the gas rises from the inlet pipes, filling the upper part of the space beneath the crown.

As the holder rises, the inner lift cup engages with the grip, or inverted cup of the next lift, carrying enough water to make the seal against the internal gas pressure.

The action of the seal is simple, but as it is necessary to provide against the water overflowing the top of the grip, and to prevent the oil on the surface of the tank water from getting into the cup, the proportions of the depth of cup and grip sheets and the determination of the proper level, relative to the tank overflow, require considerable study, and careful full size laying out. Methods controlling the passage to and from the cup when properly worked out, aim to prevent violent fluctuations, and escape of the gas in the grip.

When a holder is inflated, the cup will fill, in cold weather from the condensed steam, or water used to prevent freezing. This excess water is taken off through an inside overflow, to prevent overflowing the grip, or overflowing the cup plate, where an extended grip sheet is used, running down the legs, or inside stiffeners, where there is danger of forming ice. (Fig. 10.)

Each lift is provided with vertical stiffeners, secured to the inside, having two purposes, one to prevent buckling of the thin shell when the holder is landed, the other to furnish guides for the rollers attached to the under side of the cup of the next inner lift. This roller pressure in the case of deep lifts, is so considerable that it necessitates the use of a leg as deep and stiff, as the space available permits. The most effective design is a ship channel with continuous angles bolted to the shell sheets. Cutting these angles into short lengths or knees is a practice which fails to make sufficient use of the rather limited radial distance available between cup and shell. In a large holder the maximum load on the lower rollers may run as high as 7 500 lb., which applied to the web of a 6 in. standard channel on a 40 in. span is excessive.

Early holder designers made great efforts to secure a stiff leg, but the use of outside members, called friction plates greatly

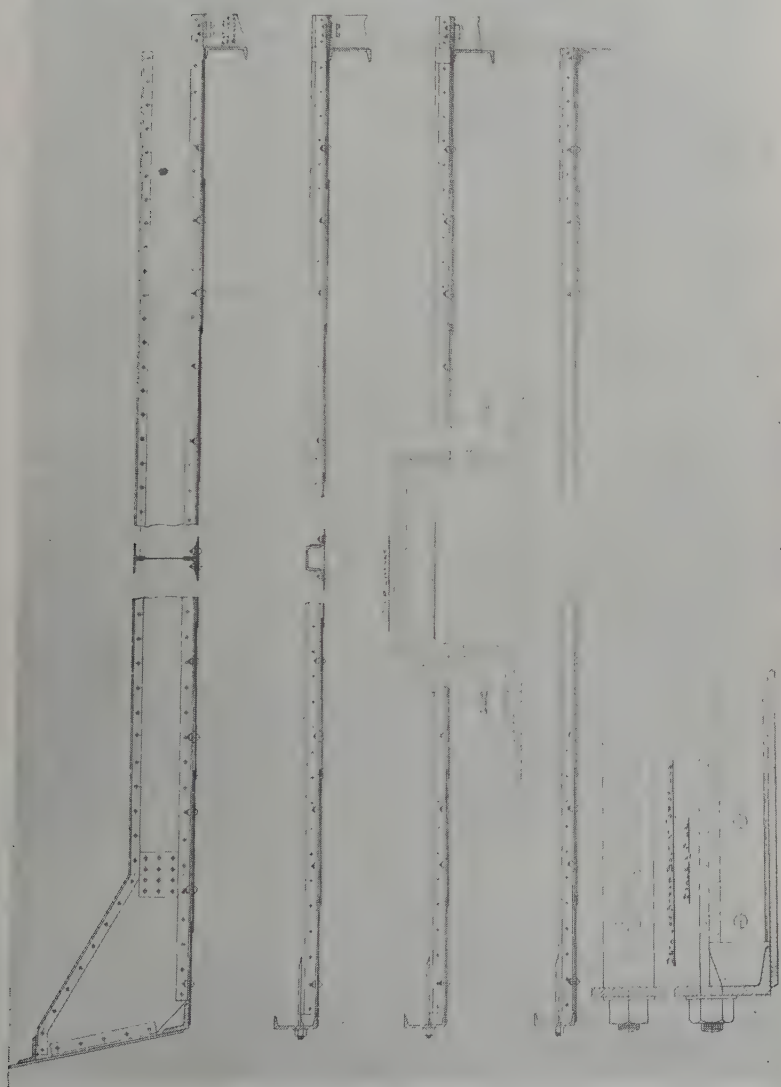


FIG. 10. — DETAILS OF LEGS OR VERTICAL STIFFENERS.

increases the cost of fabrication and erection. Further, where the plates are secured by bolts passing through the shell and legs, the moisture remaining under the plates, as the lift rises from the water, causes rust on the sheets and it is here that the first signs of leaking are found.

In old holders, removed after long use, it is invariably found that sheets under friction plates are eaten through.

English constructors do not use continuous sheets, merely running the sheets from leg to leg. They are thus enabled to use a deep leg and apply outside guiding by rollers carried on the grips. In this country the extra expense for friction plates and rollers is not considered necessary in usual designs, but where a lift rises above the frame, such support and guiding must be used.

The channels, the horizontal members of the cups and grips, bent to a circle, are from 8 in. to 12 in. deep horizontally in the large holders, and when the cups fit, with the rollers closely adjusted, form a circular horizontal girder of some stiffness, but when not well supported by the frame, cannot of themselves carry the wind loads without noticeable distortion.

In England, most of the large holders are made with Pigott cups, constructed of plates pressed into U shape. This cup and grip has great stiffness but it makes difficult attachment for goosenecks and brackets, and requires exceedingly great care in fitting up, to keep anywhere near to the true circle.

The curb uniting crown to shell is in compression, due to the tension of the crown expressed by

$$\frac{P \pi R^2}{2 \pi R} = \frac{PR}{2}. \quad (\text{Fig. 11.})$$

P = pressure per sq. ft.

R = radius of crown.

r = radius of holder.

This tension exerts a uniform radial pull on the curb, the parallel components producing compression. Thus $\frac{PR}{2} \times 2r$ gives the total compression on the curb, but as there is a section of curb at each end of a diameter, the compression on the section is

$$\frac{PRr}{2} \times \cos a.$$

As α does not exceed 15° , $\cos \alpha$ is usually taken as 1. The section resisting compression is made up of the curb angles, the outer course of crown and the top course of the shell, which are made relatively thick.

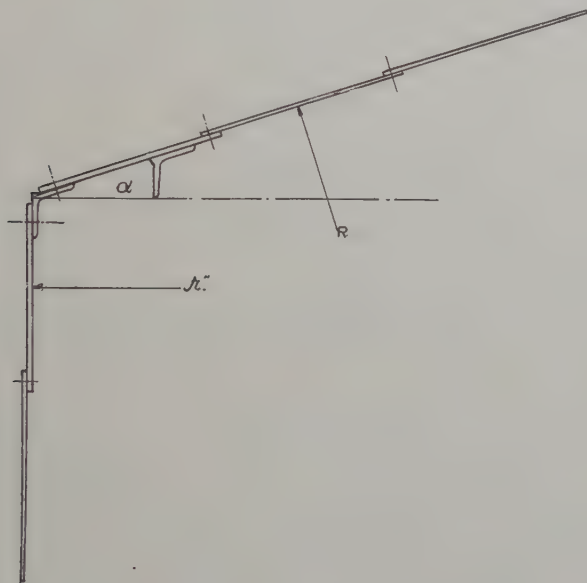


FIG. 11. — SECTION OF TOP CURB OF HOLDER.

Assuming a holder giving 20 in. pressure, $20 \times 5.2 = 104.00$ is the pressure in lb. per sq. ft. From this is subtracted the weight per sq. ft. of the crown — say 11 lb., leaving 93 lb. net.

Assuming $R = 400$ ft., $r = 125$ ft., we have

$$\frac{93 \times 400 \times 125}{2} = 2\,325\,000 \text{ lb. compression.}$$

There is a slight addition to compression, about 3 per cent. due to wind and snow. Assuming 12 000 lb. per sq. in. allowable, about 200 sq. in. must be provided. In this case, it is necessary to build a box curb, as the two angles and two plates can hardly be designed to furnish over 165 sq. in.

The distance to which the compression extends from the curb both on crown and shell is controlled by the thickness of the

plates. A neutral line exists, but is not easy to locate, unless a thin plate is directly joined to one much thicker, but this is not good practice as it produces a very uneven surface — when the holder is fully inflated.

Intermediate courses, tapering off the drop in thickness, are used, but their resistance is not considered in figuring the compression section. The triangular top of the inner lift legs, acts as a very efficient stiffener for the curb, but in extreme cases intermediate stiffeners should be used.

The crown sheets are from No. 10 BWG to $\frac{3}{16}$ in. thick, in special cases, up to $\frac{7}{16}$ in. In the large holders the pressure demands double riveting and in at least one case, three rows of $\frac{3}{8}$ in. rivets were used.

Shells are now usually of No. 10 BWG to No. 8 with two rows of $\frac{5}{16}$ in. rivets, where diameters and pressures demand.

In one large holder the stresses are as follows:

Tension on crown sheets.....	11 000 lb.
Shear on crown rivets $\frac{3}{8}$ in., 3 rows.....	7 200 lb.
Bearing of rivets in holes.....	10 500 lb.
Tension on shell sheets.....	9 300 lb.
Shear in $\frac{5}{16}$ in. rivets, 2 rows.....	5 300 lb.
Bearing of $\frac{5}{16}$ in. rivets in No. 10 sheets.....	8 900 lb.

Where hot riveted, all edges of plates are calked. In the thinner sheets, riveted cold, rivets being at 1 in. pitch, it was early the custom to make joints with tape and red lead, with lead strips, with red lead, or with black oxide of manganese. When sheets were less than No. 11 BWG and coal gas was the only kind in use, these gave satisfactory results, but as highly carburetted water gas came into use, much condensation of oil took place, especially on the cold side, and this oil would penetrate the joints. Sheets laid metal to metal if No. 11, or thicker, may be calked, but with thinner sheets, the use of sal ammoniac gave the best results.

At present there is no demand for sheets thinner than No. 10, the candle power and heat value of gas is very much lowered, and in most large works, mixed gas is used, so that the joint problem is not serious and the edges of the sheets may be calked

or not as necessity arises. It is possible to fabricate, fit and drive the joints, in such manner, that little calking is needed.

In the southwest and west, where gas is made exclusively from oil, there is but little condensation on the inside of holder sheets as the temperature rarely falls to the point of serious condensation. A cold north wind is a great condenser.

GOOSENECKS.

In the early days, the number of goosenecks for guiding was much less relatively to diameter than at present, and they carried only radial rollers. Many large installations with radials only lasted their allotted time without failure. Holders 140 ft. diameter by 35 ft. deep, were built with 6 in. cup channels, and 12 radial rollers, no tangential rollers. Such holders were built in considerable numbers, and lasted as long as wanted — 40 to 50 years.

At present the tendency is to force the use of tangential rollers on smaller sizes. It is only a useless expense on a holder of less than 1 000 000 ft. capacity.

Where tangential rollers are used, the roller shafts and their connections to the gooseneck should be thoroughly designed, or, after all, they may be useless, from excessive deflection, and the load will go to the radials.

This question of relative effectiveness of radial and tangential guiding has been much debated. The frame members being stiffer radially than tangentially it is easy to assume that radial rollers take the greater proportion of the load, and this is undoubtedly true for the inner lift, where the goosenecks are secured to the very rigid curb of the crown, but on lower lifts, where goosenecks are attached to the grips, the radial support is probably not so good as the tangential, as the moment of the radial load exerts a twisting effect on the grip which is not very rigid against such a load. In many old holders it is possible to see webs of grip channels, perceptibly out of level radially.

To secure the greatest possible resistance of the grip channel, it is necessary to attach the leg to the channel web, very efficiently.

In figuring roller pressures, refer to diagram for 20 standards,

$$\text{Maximum roller pressure} = \frac{\text{wind and snow}}{14.43} = 9\,770 \text{ lb.}$$

This may have an overhang of $4\frac{1}{2}$ ft. resulting in a moment of 527 600 in. lb. From this figure, the construction and connection of the goosenecks may be designed.

Wide grips and cups also afford very effective tangential resistance and provide for substantial gooseneck connections.

In England there is one large holder, 7 000 000 cu. ft. capacity, with radials only, and on alternate standards. This is done to reduce the size of the goosenecks allowing them to nest more compactly. Calculation shows highly excessive loads, but the high winds do not come, the holder is there and works, so why worry.

The lower curb in a single or double lift holder of large diameter relative to depth is rather difficult to design, the single angle sufficient for normal proportions being entirely insufficient. In holders of four or five lifts this curb has only a balanced load, the wind on one half the outer lift, but this becomes so considerable that a calculation should be made.

Assuming a diameter 270 ft. $\times$ 37 ft. depth, the total wind pressure on the lower curb of this lift is

$$\frac{270 \times 37 \times 16}{2} = 80\,000 \text{ lb. approximately.}$$

Taking the parallel components at all guides, less than 60° with the wind, the maximum roller load is

$$\frac{80\,000}{9.33} = 8\,700 \text{ lb.}$$

	1.00
$2 \cos^2 9^\circ$	= 1.95
$2 \cos^2 18^\circ$	= 1.81
$2 \cos^2 27^\circ$	= 1.59
$2 \cos^2 36^\circ$	= 1.31
$2 \cos^2 45^\circ$	= .98
$2 \cos^2 54^\circ$	= .69

9.33

The curb is a continuous girder, uniformly loaded, say 30 ft. between supports, 8 700 lb. in each bay. The section provided should have a moment of resistance, assuming 12 000 lb. maximum tension, of 33 or over. This may be provided by a single rolled section, but there is fabricating advantage in a flat bar, with an angle on the inside edge, connecting to the lower course of the shell. This is easier to butt strap efficiently, and the attachment of the roller brackets is less difficult.

All the rollers have adjustment, and brass bushing is desirable.

The calculation of loads on goosenecks, frame parts, foundation bolts, follows as a development of the formula $\sin^2 + \cos^2 = 1$, and passing around a circle, taking the angles at N points

$$N [\Sigma \sin^2] + N [\Sigma \cos^2] = N, \text{ also } N \Sigma \sin^2 = \frac{N}{2}, \text{ and } N \Sigma \cos^2 = \frac{N}{2}.$$

If you consider a derrick mast, supported by N guy lines, reaching to points of support in the same plane as the top of the mast you have the situation very close to the problem of loads and supports in a gas holder.

If the guides reach to the ground, they are analogous to the diagonals in the frame.

The loads in radial supports are proportional to the cosines of the angles which they make with the direction of the load, but the effective resistances of the strains in the supports are also proportional to the cosine of the same angles; that is, a strain of 10 000 lb. in a support, not in line with the load is not so effective as an equal strain in a support in line with the load. Consequently the resistances in a direction parallel with the load are proportional to the squares of the cosines of the radial angles with the direction of the load. Where supports are effective in both tension and compression, all points may be considered, but in a gas holder the rollers have push only, no pull, and in the guide frame the diagonals are designed to carry tension only.

GUIDE FRAME.

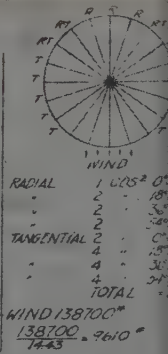
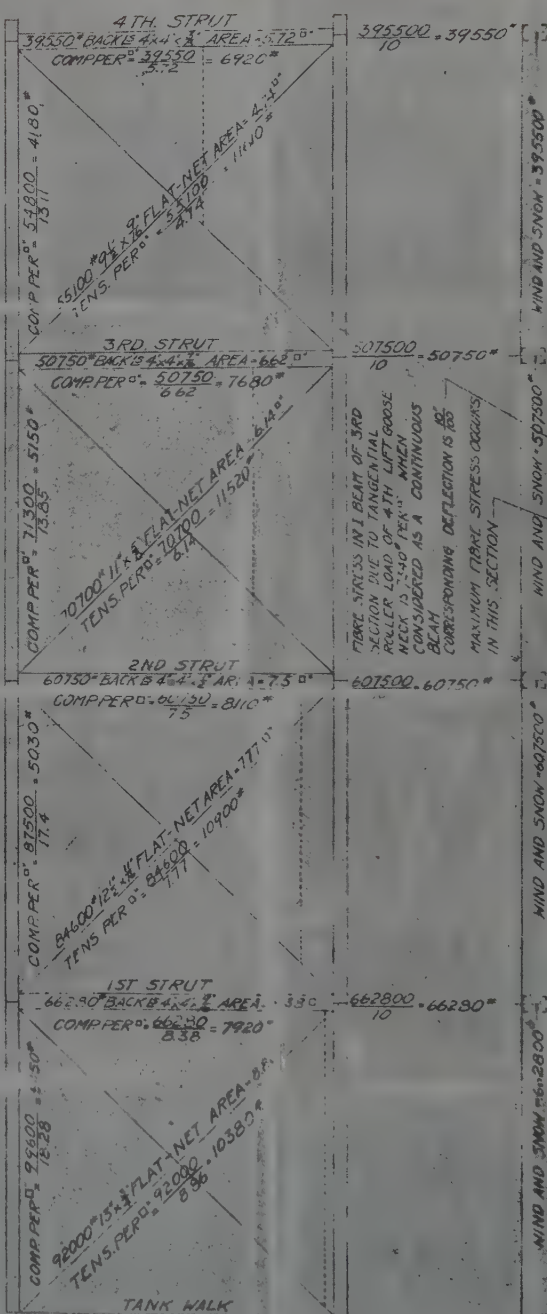
The holder being top heavy or in unstable equilibrium must, of necessity, be guided. The lower curb rollers run on guides secured to the inside of the tank, but a structure must be built

BACK IS $4\frac{1}{2} \times 4\frac{1}{2} \times \frac{1}{2}$ AREA = 7.5"
 $\frac{1}{2} \times 15 \times 33 = 99$
 TOTAL = 174"
 WIND AND SNOW = 58800"
 METAL = 28700"
 TOTAL = 87500"

BACK IS $4\frac{1}{2} \times 4\frac{1}{2} \times \frac{1}{2}$ AREA = 7.5"
 $\frac{1}{2} \times 15 \times 33 = 99$
 TOTAL = 174"
 WIND AND SNOW = 58800"
 METAL = 28700"
 TOTAL = 87500"

BACK IS $4\frac{1}{2} \times 4\frac{1}{2} \times \frac{1}{2}$ AREA = 6.5"
 $\frac{1}{2} \times 12 \times 25 = 1385$
 TOTAL = 1385"
 WIND AND SNOW = 49100"
 METAL = 22200"
 TOTAL = 71300"

BACK IS $3\frac{1}{2} \times 3\frac{1}{2} \times \frac{1}{2}$ AREA = 5.76"
 $\frac{1}{2} \times 12 \times 25 = 1385$
 TOTAL = 1385"
 WIND AND SNOW = 38500"
 METAL = 16500"
 TOTAL = 54800"



KINGS COUNTY
 LIGHTING COMPANY
 6001030 CUFT. GAS HOLDER
 IN STEEL TANK
 STAINLESS ON GUIDE FRAME

WIND 141000"
 141000 = 9770"
 1443

NOTE - GIVEN STRESSES PER 1" ARE DUE TO THE
 SIMULTANEOUS OCCURRENCE OF THE MAXIMUM
 WIND AND SNOW LOADS BOTH ACTING IN THE
 SAME DIRECTION.

FOR TOP SECTION OF
 GUIDE FRAME SEE C 24.5, 723

This figure 66 300 lb. is also the horizontal component of the tension in the diagonals, leading to an actual tension of 92 000 lb.

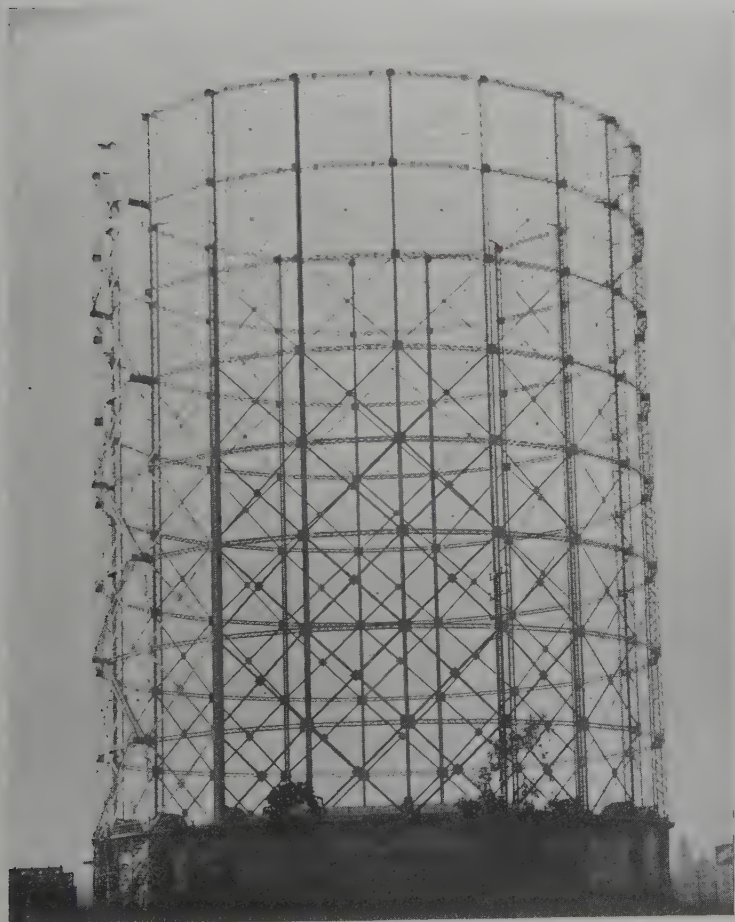


FIG. 13. — GUIDE FRAME WITH TWENTY STANDARDS 239 Ft. HIGH.
Total height above foundation, 288 ft.

This frame being of unusual proportions, higher than the diameter, the strains are kept low to limit deflection at the top. the tension per sq. in. 10 400 lb. a $3\text{ in.} \times \frac{3}{4}\text{ in.}$ flat was used.

The gooseneck loads run from 5 000 to 9 800 lb., which fix the central load on a section of standard — the standards 42 in. deep may be latticed, or web plate, — the front and back flanges weighing 55 lb. and 61 lb. respectively.

A center load — 9 800 lb. on a continuous girder 30 ft. long by 40 in. deep having a flange area 18 sq. in. produces a stress per sq. in. about 600 lb. Tangentially 9 800 lb. on a continuous 15 in. I — 42 lb. per foot, produces a maximum strain of 7 500 lb. per sq. in. and a deflection of 0.1 in. in a beam 30 ft. long.

The maximum upward pull, or lift at the base of a standard on the windward side is figured thus:

Outside diameter 196 ft. 9 in. — say 200 ft.

Total height 239 ft.

$$\frac{239 \times 200 \times 16 \times 120}{\frac{N}{2}} = 92\ 000\ \text{lb.}$$

$$\frac{\text{Weight of frame}}{20} = 60\ 000\ \text{lb.}$$

90 000 — 60 000 = 30 000 lb. vertical pull
to be absorbed by tank connections —

90 000 + 60 000 = 150 000 lb. vertical compression
to be resisted by tank connections, say thirty $\frac{7}{8}$ in. rivets in single shear at 7 500 lb. shear per sq. in.

The section of standard — with two angles and channel cover, at the back and two angles and 15 in. I beam at the front, is quite rigid and offers a large margin for emergencies, not covered by the assumptions. The maximum compression on the back flange is 5 450 lb. per sq. in.

$$\text{Radius of gyration of 12 in. channel} = 4.61, \quad \frac{L}{r} = \frac{360}{4.61} = 78.$$

The maximum compression on the back flange of a standard is considered to be in the bays where the maximum load on diagonals occurs.

The need of web stiffeners on standards is limited to the necessity of keeping the flanges in line, and square with the web, one at panel points and one at the middle of the length being sufficient, the axial loads being low.

The horizontal members are designed for compression although they are subject to a small amount of tension on the leeward side. They are made as deep radially as will permit the proper clearance of the holder sections.

When the holder is down, they come into play, in the united structure as a circular girder.

The inner members are connected to the standards as near to the front flange as possible, and all connecting plates should be continuous, so that rivets may be in shear, rather than in tension. It is possible to design a frame with no tension rivets in critical positions.

In the example taken, the horizontals are box shaped, of four angles united by lattices, the figure being 18 in. deep vertically by 24 in. radially. The least radius of gyration is approximately 8 in., the length of the member 360 in., thus $\frac{L}{r} = 45$, which permits a safe load in excess of that calculated, about 8 000 lb. per sq. in.

In order to secure rigidity of the guide frame, all joints between members should be made with rivets, with the single exception of the wind ties, where bolts and turnbuckles are permissible to accomplish adjustment.

In designing joints at the ends of a diagonal, sufficient rivets should be used to take up at 10 000 lb. per sq. in. shear a load which could be produced by a stress of 16 000 lb. per sq. in. on the net section of the diagonal. All other joints, especially at the panel points, should also be provided with an excess of rivets, the object being to have an abundance in case some should be loosened by racking and vibrations due to the impulse of the wind. This excess of rivets also serves to keep the shear and bearing well within the allowable limits used in approved bridge construction.

As the loads which must be resisted by a guide frame may be applied from any direction, it follows that all members of the same kind which are situated in the same section of the guide frame should be of identical design. For this reason only those calculations are made which are necessary to determine maximum stresses. It is to be observed that in the calculations the

entire snow load is assumed as being taken by the goosenecks at the top of the inner lift. Actually, part of this load will be taken by other goosenecks than those on the inner lift, but to determine how much would be impossible because the rigidity of the gas holder bell — an uncertain quantity — would be involved. Therefore the above assumption is made, as it gives loads which are greater than those which would result from any other assumption.

The choice of either flats, channels, or angles for use as diagonals is dependent upon circumstances. Flats are less in first cost because the price of the metal in them is generally less per pound than for the alternate shapes, and also because the shop and field work is less expensive. When either angles or channels are used it is necessary in order to properly distribute the stresses about the center of gravity of the section, to use angle knees on the flanges. When the diagonals are extraordinarily long it is advisable to use angles in order to prevent undue swaying in the wind.

The difficulty of keeping a guide frame properly painted, with the consequent liability to corrosion, makes it advisable to use no metal in its construction thinner than $\frac{1}{4}$ in., while for the more important members such as the diagonals and back angles in the struts and standards, the metal should never be less than $\frac{5}{16}$ in. in large guide frames.

The calculation of a frame is merely the proper distribution of the normal weight. In exceptional cases frames may run as low as .13 lb. per cu. ft. of capacity of the holder — rarely over 21 per cent. From 16 per cent. to 18 per cent. of the capacity is sufficient where the proportions of diameter and height are usual. Where the calculation results in a weight outside these limits it should be revised very carefully. In England much more material is used in frames, one large holder running to 40 per cent., while from 25 per cent. to 30 per cent. are common. A 12 000 000 ft. holder, recent design, gives 28 per cent. In Germany very light constructions are the rule. This observation applies to the holder design as well, and there have been failures, notably of the top curb of an 8 000 000 capacity holder in Vienna, clearly under figured.

The total weight of the structure of a tank holder frame and connection will run approximately 1 lb. to the cu. ft. of holder volume, being a little more or less according to circumstances. The German builders claim that in a holder of 8 800 000 cu. ft. capacity, with a so-called spherical tank shell, the entire weight is as low as .655 lb. per cu. ft. of volume.

The following pages are extracts from specifications as to materials, fabrication and design:

Material. — All plates $\frac{3}{16}$ in. thick and heavier, and all shapes shall be of open-hearth steel having an ultimate tensile strength of 55 000 to 65 000 lb. per sq. in., an elastic limit of not less than 50 per cent. of the ultimate tensile strength and an elongation, in a length of 8 in., of approximately $21\frac{1}{2}$ per cent., with modifications for thin and thick material. Standard test pieces shall stand bending through 180 degrees to a diameter equal to the thickness of the piece tested without fracture on the outside of the bend. This is the material called "Class A Structural Steel" in the Manufacturers' Standard Specifications as revised to 1919.

Gas-holder sheets No. 8 BWG and lighter shall be of the best blue annealed gas-holder steel presenting a clean and smooth finish. Samples cut from the finished sheets shall stand bending flat on themselves, when cold, without fracture on the outside of the bend.*

The following parts may be made of wrought iron: packing, wind ties at the top of the guide frame, special "U" section for legs, stiffening bead for cups and grips, guide rail chairs and connections for attaching legs to grip channels; also lattices and tank walk braces, when made of flats.

The weights per sq. ft. shall determine the thicknesses of plates and sheets in all cases and when these thicknesses are expressed in fractions of an inch or by gauge numbers they are only nominal designations.

Rivets $\frac{3}{8}$ in. diam. and smaller shall be the equal in quality, standard gas holder rivets. Rivets $\frac{1}{2}$ in. diam. and larger shall be of the quality called "Structural Rivets." Rivets may be of either iron or steel, excepting that those in the tank shell shall be of steel.

The parts mentioned below may be of genuine wrought iron made from muck bars produced by the puddling furnace process.

All grip plates, the lower course of each lift, the top course of the second, and other lifts, the top course of tank and all handrails.

Treatment. — All material over $\frac{5}{8}$ in. thick in tension members shall be drilled; material over $\frac{3}{4}$ in. thick in any part shall be drilled, excepting that packing may be punched. Holes not giving enough clearance for the entrance of rivets at assembling may be reamed or gouged. At assembling the drift pin may be used for drawing pieces together. Calking edges may be beveled

* Iron sheets may not stand this test.

either by planer or by shear, according to the thickness and convenience of handling. On plates over $1\frac{1}{8}$ in. thick all mill sheared edges shall be planed, an amount equal to half the thickness of the plate being removed from each edge. The holder sheets may be ground on an emery wheel, after being punched, to remove the punching burrs.

Calking. — Calking may be done either by hand or by pneumatic hammers, at the option of the contractor.

Driving of Rivets. — All rivets driven in the shop shall be upset by hydraulic machines so far as practicable; those driven in the field may be upset either by hand, by pneumatic hammers or by hydraulic machines, at the option of the contractor.

Rivets $\frac{3}{8}$ in. diam. and smaller may be driven cold; all other rivets shall be driven hot, excepting that rivets $\frac{1}{2}$ in. diam., if of suitable quality, may be driven cold by hand.

It is the aim to avoid hand driving of rivets as much as possible, and it may be resorted to only under exceptional conditions, from inaccessibility, breakdowns, or urgent necessity for hastening completion of certain parts. Hydraulic compression riveters are preferred, but pneumatic hammers may be used (at the option of the contractor) where more economical, more convenient, or more rapid.

Paint in Shop. — Before leaving the shop all material shall receive one coat of lead paint, excepting along calking edges and the margins of sheets where they are to be rivetted together in the field. All surfaces coming in contact shall be painted before being assembled for riveting in the shop. Before being painted all material shall be cleaned of dirt, rust and such mill scale as can be removed by the careful use of wire brushes.

Paint at Erection. — At erection the under side of the tank bottom shall receive one coat of lead paint after being riveted and before being lowered to the foundation; the inside of the tank shall receive one coat of the same paint before being filled with water.

All rivets, excepting those along calking edges, shall be painted immediately after being driven. Calked joints shall be painted immediately after being calked. The seams of the holder shells and crown shall be painted, immediately after being riveted, both inside and outside.

Finally, after completion, the entire structure — holder, frame and tank — shall receive one coat (on the outside) of paint to be selected.

The final coat of paint shall not be applied until suitable weather arrives (any delay for this reason is not to be counted in fixing the actual date of completion of the contract; not over 1 per cent. of the total contract price is to be withheld on this account).

General Design. — The depths of the lifts are arranged to land the outer lift grip above the top of the tank, the fifth, fourth, third and second lift grips above and the inner lift curb even with the top of the tank. (The landing blocks in the tanks are designed to land the cups of the inner, second, third, fourth and fifth lifts at the same level — 12 in. above the bottom of the tank).

The above arrangement of grips provides against overflowing the channels during cupping and uncupping.

Riveting. — Rivets $\frac{3}{8}$ in. diam. and smaller, in the shells, shall be button head, driven on the inside and not set. Hot rivets are usually driven on the outside and set, but some rivets, because of their situation, must be driven on the inside and need not be set. Rivets in the crown, if driven by hand, shall be upset on the outside; if driven by a hydraulic machine they shall be upset on the inside with flat dies; if pneumatic hammers are used the rivets shall be driven on the outside and set.

In the calculation of the thickness of plates in the shell all holes for rivets 1 in. diam. and smaller are considered to be $\frac{1}{16}$ in. larger than the nominal diameter of the rivet and all holes for rivets over 1 in. diam. are considered to be $\frac{1}{8}$ in. larger than the nominal diameter of the rivet. In the calculation of the shear all rivets 1 in. diameter and smaller are considered to be of the nominal diameter and all rivets over 1 in. diameter are considered to be $\frac{1}{16}$ in. larger than the nominal diameter. In the calculation of the bearing all rivets are considered to be $\frac{1}{16}$ in. larger than the nominal diameter.

Note. — Rivets 1 in. diameter and larger may be driven with a low head inside, the hole being slightly countersunk.

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